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CZM

PRODUCTIVITY (STANDING CROP) OF *Spartina alterniflora* and COMMUNITY ANALYSIS OF SELECTED SALT MARSHES ALONG THE COAST OF MASSACHUSETTS

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INTRODUCTION

This report is one part of a five part report concerning the habitats of the Massachusetts coastal zone. Four sections of the report describe the flora and fauna of the coast, the fifth part is a sensitivity analysis of the various coastal habitats to different human activities. The part of the report dealt with in the present study, describes the flora of the salt marshes of the Massachusetts coast.

The objectives of this part of the report are:

1. describe the significance of the coastal zone (1^o salt marsh) ecosystems;

2. map the coastal ecosystems (submitted under a separate cover);

3. determine the standing crop and species composition of the coastal salt marshes;

4. apply the field data gathered in objective #3 to the mapping project of objective #2 to produce detailed maps of the Commonwealth's salt marshes; and

5. To rate the sensitivity of the coastal ecosystems to human activities (considered under separate cover).

BACKGROUND

Intertidal salt marshes are an important feature of the Massachusetts coast. Perhaps the most persuasive argument for their protection is their role in the production of organic matter which is released into estuarine and nearshore marine waters. Biologists have been pointing out the importance of salt marshes in organic production for the past decade. It is now common knowledge among coastal biologists and planners that any attempt to maintain nearshore fisheries requires the protection of salt marshes. In terms of organic output into other ecological systems, salt marshes are among the most productive in the world. It is in their role as organic exporters that they reach their greatest usefulness.

The production of organic material begins with light energy falling on the grasses of the open marsh. This energy is converted to organic products by photosynthesis. The marsh is quite efficient at this task. The important aspect of this process is what happens to this organic matter. Ordinarily, in terrestrial ecosystems, much of the plant productivity is returned to the soil. However, man learned to utilize this "wasted" productivity when he developed agriculture. By planting and harvesting, man caused the exportation of plant products from one ecosystem (the field) to another (man's community). Nature carries on the same sort of exportation of productivity in the salt marsh.

At the end of summer, when the growth of marsh grasses ceases, stems and leaves of the plants begin to die and breakoff. Incoming tides pick up this material (called detritus when it starts to decompose) and carry it back and forth across the marsh. Eventually the tides carry it out into the open waters of the estuaries and bays. All this time, microbes are acting on the plant particles and breaking them down into smaller and smaller pieces. Other marine organisms ingest the particles of detritus, digest the microbes, and egest the particles. Once back in the water the particles are recolonized by more microbes, only to be ingested again in a continuous recycling process until the detritus particle is completely decomposed. The food web continues as larger organisms eat the smaller organisms that in turn have eaten the microbes that once fed on the plant particles. This process continues until the level of the top carnivore, such as a shark, or the omnivor, such as man, is reached.

This type of food web is typical of a detritus system. It is contrasted with the direct grazing food chain, an example of which would be the food chains in a meadow. Because of the continuous recycling of the plant remains, in the detritus system, a very complex and large food web can be supported. It is the high animal productivity of this food web that makes the estuarine and nearshore system so significant. Without the input of organic matter from the photosynthetic system of the salt marsh (primarily grasses and associated algae) this complex food web could not exist.

Other important sources of organic production in the nearshore environment are free floating plankton and bottom rooted macrophytes (e.g., eel-grass). The relative proportions of total organic contribution of these three major photosynthetic systems varies along the coast and with the season of the year. A recent study by Nixon and Oviatt (1973) in Rhode Island provides specific data on the importance of the three systems for our latitude. Whatever the precise proportions, the contribution of salt marshes is very significant.

While we can be assured that in terms of productivity (as well as other criteria such as storm flood protection, erosion control, wildlife habitat, and aesthetics) salt marshes are natural resources of great value. However, not all salt marshes have the same degree of productivity. Likewise, not all parts of an individual marsh have the same relative significance to marine systems. In any attempt to evaluate marshes and their role in the estuarine food web, it is necessary to consider which marshes and what portions of those marshes are most significant, and how they compare to each other. In this kind of evaluation, it is important to recognize that we are looking at only one of several possible criteria, in this case, we looked at productivity. Arguments for marsh preservation should not be made on a single criterion alone, the overall system must be considered. When preservation of any particular marsh is discussed, productivity determinations can contribute to the decision-making process. In terms of this consideration we have endeavored to look at the variations in marsh productivity and species composition along the Massachusetts coast for two reasons: (1) to determine the general range of marsh productivity from north to south along the coast and to then classify certain marshes according to their productivity (in this case measured only by standing crop) and (2) to survey selected marshes as ground truth for aerial photography to be used in a mapping project for the whole coast. The mapping project was designed to locate the most significant marshes along the coast and to give some general idea of their ecological value in a preliminary evaluation. More intensive studies would have to be conducted on specific marshes to fully analyze their value. However, such intensity was not the purpose of this first identification of some of the ecologically significant marshes on the coast of Massachusetts.

The organic contribution of a salt marsh to the marine environment varies according to the relative elevation of the marsh and the frequency with which it is flooded by daily tides. The salt marsh can be divided into two basic zones. The first, the high marsh which is flooded only during high spring tides and storms and is dominated by salt tolerant grasses such as salt meadow cordgrass (*Spartina patens)*, spike grass *(Distichlis spicata)*, salt grass *(Puccinellia maritima* - more common north of Massachusetts), black rush *(Juncus gerardii)*, seaside goldenrod *(Solidago sempervirens)*, sea lavender *(Limonium carolinianum)* and others. The second, is the low marsh, flooded by every diurnal tide and dominated by salt marsh cordgrass *(Spartina alterniflora)*, and macroscopic algae such as rockweed *(Fucus spiralis)*. The low marsh is the portion of the salt marsh system which contributes the greatest amount of organic matter to the sea. Only one species of higher plant, *Spartina alterniflora*, can thrive in this environment. *Spartina*, along with the marine algae found around it, makes the low marsh a prime photosynthetic system. The low marsh can be further divided into two parts; the upper low marsh where the *Spartina* plants are relatively short, and the lower low marsh where the plants are conspicuously tall. The lower low marsh zone grades into the deepest waters that flood the marsh. It is found along creek banks, or on the gradually sloping flats, at the edge of the marsh where the marine environment begins. Since this zone is lower in elevation than the rest of the marsh and is flooded adequately every day, the environmental conditions favor the robust growth habit. It is the robust growth habit of the lower low marsh form of *Spartina* which accounts for the great productivity of this zone. Being readily flooded, and near the open water, the organic matter produced is carried into the marine environment.

The upper low marsh begins a short distance back from the lower part, as the elevation rises slightly to a flat region that is still flooded by daily tides, but sometimes barely so. Here the growing conditions are not the best for *Spartina*. The *Spartina* found here does not grow as tall nor as vigorously as does the form found further down the marsh profile. Also, this zone may not be flooded as deeply or quickly with the rising tide. In some places ponds of standing water may remain when the tide is out if the drainage is not adequate. Thus, the upper low marsh, while still in the daily tide range (neap tide range), does not have as high a rate of production or export as does the lower low marsh. In any case, the entire zone occupied by *Spartina alterniflora*, whether tall or short, accounts for the major export of the marsh. Those marshes with wide and extensive zones dominated by the tall form (and to a lesser extent by the short form) of *Spartina alterniflora* can be considered as having the greater rate of production and export to the estuarine and nearshore environment. On the other hand, marshes that are higher in elevation, and dominated by *Spartina patens*, out of the normal reach of the daily tides except during the spring tide cycle, are likely to have a considerably lower contribution to the estuary. Therefore, the area as well as the nature of the growth form of the low marsh must be considered when evaluating the contribution of any given marsh to the marine environment.

The standing crop of *Spartina alterniflora* was collected and used as a criterion for ranking specific marshes in this study. In addition, an estimate was made of the portion of the marsh occupied by the low marsh along the transect lines. A better estimate of this parameter will be made from the mapping project. The standing crop, or the amount of plant material present at any given time, is merely an estimate of productivity. This quantity represents the amount of organic production that remains after the plant has respired a small portion for its own life needs and as such is an estimate of <u>net</u> productivity. It is the net productivity that is used by all other forms of life. A more accurate measure of productivity would be to determine rates of photosynthesis, but such work requires a very elaborate research project, which was beyond the scope of this survey. Standing crop can be determined merely by cutting the grass down and measuring its biomass in dry weight. However, there are certain flaws in this method. Since the result one gets from this process is net productivity, it does not indicate how much plant material was utilized before harvest. Organic matter was removed by the grazing of insects and other organisms before the collection was made. Also, it does not take into account the amount of material that has already been transported out of the system, by leaves breaking off and floating away or dying and decaying at the site. Finally, the amount of standing crop varies with the time of collection. Samples taken in the early part of the growing season will be of considerably less volume than those taken at the end of the season. For this reason, most standing crop estimates are made as close to the end of the normal growing season as possible. This practice however, increases the significance of the flaws mentioned above. This technique is a measure of biomass at one moment in time but does not take into account ongoing processes. In addition, the standing crop of leaves and stems does not indicate how much material was translocated into the roots below -- in some species, such as *Spartina*, this can be a substantial proportion of the gross productivity. As a matter of fact, the organic production which goes into the root and rhizome region is lost to the estuarine system. The material that goes to keeping the roots and rhizomes alive in time, adds to the growth and development of the peat layer. The more organic material that accumulates in the peat, the faster the peat layer will grow and raise the level of the marsh beyond the reach of the tides. This is part of the natural succession that occurs in salt marshes - as organic content of the substrate increases, the marsh changes; first from lower low marsh to upper low marsh, then to high marsh. The organic matter added to the peat substrate causes the marsh to build itself up out of its prime habitat, and eventually put itself out of existence. This process is common in all successionary sequences. The salt marshes represent a very early stage in plant community succession. Rates of elevation increase in the marsh depend on tide ranges, rates of sedimentation, productivity, and sea level change.

Even though there are flaws, the standing crop method of determining productivity, provides the only means of rapidly obtaining an estimate of the amount of organic material available for transport into the marine environment. Essentially all of the plant material measured by this method will enter the water during the course of the year and become part of the food web. If anything, the standing crop method leads to an underestimate of the organic matter being exported to the sea. Likewise, it is an underestimate of the overall productivity of the marsh, even the low marsh. When we measured only *Spartina alterniflora*, as in this study, we did not get any information on the contribution made by algae, both microscopic and macroscopic. Algae live on the mud and around the stems of the *Spartina* plant. A complete evaluation of a marsh should include these plants, even though they account for a much smaller portion of production than the grass (although in some marshes the standing crop of rockweed and other macroscopic algae can be quite high). Unfortunately, it was beyond the scope of this study to include the algal fraction. Thus, it is important to consider that the figures given here are underestimates.

A final point in regard to the selection of marshes for inclusion in this study; the marshes selected for sampling merely represent a range of marsh types found in the Commonwealth from north to south. This study is not to be considered a complete survey of all the major salt marsh areas in Massachusetts. Such a survey would require many more resources than were employed in this initial attempt to evaluate certain marshes. The data collected were intended to be used in conjunction with aerial photography, so that the map made from the photographs could then be used in conjunction with the field measurements in attempting to classify the major marsh areas of the Commonwealth. The transect and standing crop data were used as ground truth for the imagery, providing the information for meaningful interpretation of the photography. Therefore, the marshes discussed here should not be taken as the best, or worst marshes nor as a complete list. They are merely examples of the various types of marshes to be found along the Massachusetts coast.

We did not include certain famous marsh areas, such as the Barnstable Marsh or the Falmouth Marshes because we felt that these were adequately studied already and data were available if needed. We thought that it would be better to look at areas which had not been studied before. Also, there was not time to study the marshes of Nantucket or Martha's Vineyard. We felt that the selected sites would incorporate the range of marsh conditions and production to be found along the entire coast and could be used as models for areas identified through aerial photography.

METHODS

Twenty marshes from Newburyport to Westport were chosen for study (Table I and Figure 1). In each marsh, one or more line transects were laid out making a total of 43 transects. The locations of the transects were chosen to represent the various communities found in the marshes. Each transect ran from the upland edge of the marsh to the first creek that was too large to walk across at low tide.

In July, 1975, a point intercept method was used to sample the frequency of the plants along the transects. A metric tape was stretched along a line and at 10 cm intervals the plant rooted at that point was noted. If there was no plant, the point was recorded as either muck, sand, ditch/creek, or whatever was appropriate.

When all the data had been collected, every 10 consecutive observations (one meter) were lumped and classified into one of eight community types.

TABLE 1

Location of Study Areas

I. Plum Island: Parker River National Wildlife Refuge. Three lines were studied in the marsh west of parking area #7. The lines were 133, 197 and 432 m long.

II. Rowley: Stockyard Road. Three transects were studied at the end of Stockyard (or Stackyard) Road on Parker River National Wildlife Refuge land. All the lines were located south of the road and were 305, 219 and 171 m long.

III. Gloucester: Wingaersheek Beach. Four lines were studied in the marsh behind Wingaersheek Beach parking area. The lines were 151, 26.5, 84 and 227 m long.

IV. Gloucester: Stone Pier. Two lines were studied in the marsh by the old marina on the Jones River. The lines were north of the marina, running from the island to the river. The lines were 80 and 127 m long.

V. Gloucester: Lobsta Land. Three transects were studied in the marsh north of the causeway between the Lobsta Land Restaurant and the Buick dealer. The lines were 197, 107 and 270 m long.

VI. Quincy: Rock Island Cove. Two lines were studied in the marsh west of Rock Island. The lines were 56 and 140 m long.

VII. Weymouth landfill: Weymouth Back River. One line was studied in the marsh east of the Weymouth incinerator and landfill. The line was 145 m long.

VIII. Hingham: Home Meadows. One line was studied. It started on the Winter Street side of the marsh and was 142 m long.

IX. Scituate Country Club: North River. Two lines were studied in the marsh south of the Country Club. The lines were 136 and 526 m long.

X. Scituate Sewage Plant: North River. One line was studied in the marsh south of the point of land near the sewage plant. The line was 474 m long.

XI. Marshfield U. S. Coast Guard Station: South River. One line was studied in the marsh east of the Coast Guard Radio Station. The line was 129 m long.

XII. Duxbury: Pine Point River. One line was studied in the marsh northwest of the point of land jutting out into the river from Duxbury Beach. The line was 117 m long.

TABLE 1 (continued)

XIII. Duxbury Beach: Swimming area. Two lines were studied in the marsh west of the parking area at the public beach. The lines were 191 and 183 m long.

XIV. Duxbury: Duxbury Beach (New): Two lines were studied in the new salt marsh between the Power Point Bridge and High Pines. The lines were opposite telephone poles 40 and 45. The lines were 22 and 32 m long.

XV. Wellfleet: The Gut. Three lines were studied. They were 115, 131 and 205 m long.

XVI. Provincetown. Three lines were studied in the marsh behind the dike at Provincetown. One line ran from the road to the island, one ran from the island to Herring Cove Beach, and one ran from the island to the mainland. The lines were 364, 493 and 136 m long.

XVII. Provincetown: Hatches Harbor. Three lines were studied in the marsh southwest of the dike across Hatches Harbor. The lines were 397, 402 and 420 m long.

XVIII. Eastham: Coast Guard Beach. Three lines were studied in the marsh between Nauset Beach and Nauset Bay, south of the NPS parking area. The lines were 117, 200 and 318 m long.

XIX. East Falmouth: Great Sippewissett Marsh. Two lines were studied in the marsh east of the barrier spit. The lines were 105 and 58 m long.

XX. Westport Point: Horse Neck Beach. One line was studied in the marsh north of the west parking area for Horse Neck Beach State Reservation. It was 83 m long.

The community types were as follows:

1. Sparse *Spartina alterniflora* - *S. alterniflora* mixed with either muck or some species other than *S. patens*. This community is usually a transition zone around the salt water edge of the marsh or around a panne.

2. Pure Short *S. alterniflora* - pure stands of *S. alterniflora* less than 50 cm tall.

3. Pure Tall *S. alterniflora* - pure stands of *S. alterniflora* more than 50 cm tall.

4. Pure *S. patens* - pure stands of *S. patens*.

5. *S. patens* Mixed With *S. alterniflora* - stands of *S. patens* and *S. alterniflora* , other species may or may not have been present. This community is usually a transition between low marsh and high marsh.

6. *S. patens* Mixed With Other Species - stands of *S. patens* mixed with any species other than *S. alterniflora*. This community is usually found in the drier or less saline parts of the high marsh.

7. Mixed Other - stands of mixed species not containing either *S. patens* or *S. alterniflora*. This community is usually found at the fresh water edge of the marsh or, in the case of pure *Salicornia* around pannes.

In August the marshes were revisited to determine the stand crop of *S. alterniflora*. Random 0.25 m^2 quadrats were laid out along the part of the transect in the *S. alterniflora* community types. The aerial parts of the grass within the quadrat were collected and the height measured. The collected material was oven dried and weighed to determine standing crop.

RESULTS AND DISCUSSION

Productivity (Standing Crop) and Cover of *Spartina alterniflora*

Standing crop values for *S. alterniflora* recorded in grams of oven dry weight are presented in Figure 2. The sample sites are arranged in a north (left) to south (right) sequence. Data for both the tall and short forms of *Spartina alterniflora* are given, along with the standard deviation for each set of samples. The number of samples varies for each data point and is a function of the amount of *S. alterniflora* along the transects of each site. The basic data for this figure is presented in Tables 2 and 3 along with the number of samples taken, and the length of the transects.

The tall form of *S. alterniflora* tends to have a greater standing crop than the shor. form. Where the standing crop of the short form exceeds the tall, the density of the short form may have been considerably greater, with more plants per unit area. There is considerable variation from site to site in overall standing crop, as well as between the tall and short forms. Although marshes in the northern section had somewhat higher standing crops than in the southern areas, there does not seem to be any trend from north to south with regard to standing crop. These differences may be particular to the sites selected and not represent any real differences. Actually, one would expect that the standing crop would be higher in the southern areas.

Figure 2 shows that some marshes have significantly greater values than others in production of either tall or short forms of *S. alterniflora*. In the case of the tall form, the marshes behind the "Gut" at Wellfleet in the Cape Cod National Seashore have the highest standing crop of all sites sampled, with the Lobsta Land and Weymouth locations not far behind. All of the other marshes have markedly lower values than these three. The standard deviations for each data point show a farily consistent *S. alterniflora* stand. This indicates a degree of uniformity within the marshes, although there is some wide variation, as would be expected when sampling standing crop. Such variation should be kept in mind when considering the productivity of plant communities.

With a relatively wide range of density of standing crop in various marshes, it is possible to group them according to the data obtained. Tables 2 and 3 show the marsh sites in order of their standing crop density for tall and short forms of *S. alterniflora*. Table 2 presents the tall form data grouped in 10 g/.25m^2 increments. For comparison purposes, the Table also gives the converted value in grams/m^2 (the standard unit of presentation found in most papers). Also included is the total length of the transects studied, and the number of samples taken.

The marshes fall into five categories ranging from 23 g/.25m^2 (92 g/m^2) at Duxbury Beach (New) to 74 g/.25m^2 (296 g/m^2) at Wellfleet, a nearly three-fold increase from the lowest to the highest. Most sites fall into a farily narrow range of between 32 g/.25m^2 (128 g/m^2) and 55 g/.25m^2 (220 g/m^2). Except for the extremes of range mentioned above, it is evident that most marshes of the sampled fall within fairly predictable parameters. We can consider most of them to be of similar standing crop density. The extremes of range need further evaluations to determine the reason for their marked variations from the norm. At least for Wellfleet, we know that this particular marsh system is relatively young, and dominated by a very vigorous stand of tall *Spartina alterniflora*. Growing conditions here are ideal for the grass, which is reflected in the high standing crop figure. From these data, it is clear that some marshes have much higher productivity than others. It is necessary to look more closely at such areas when considering preservation. On the other hand, the value of some areas is considerably less than the norm. In such cases it is important to take a close look at these areas to determine the cause of such low production.

FIGURE 2

Standing Crop of *Spartina alterniflora* at Each Site

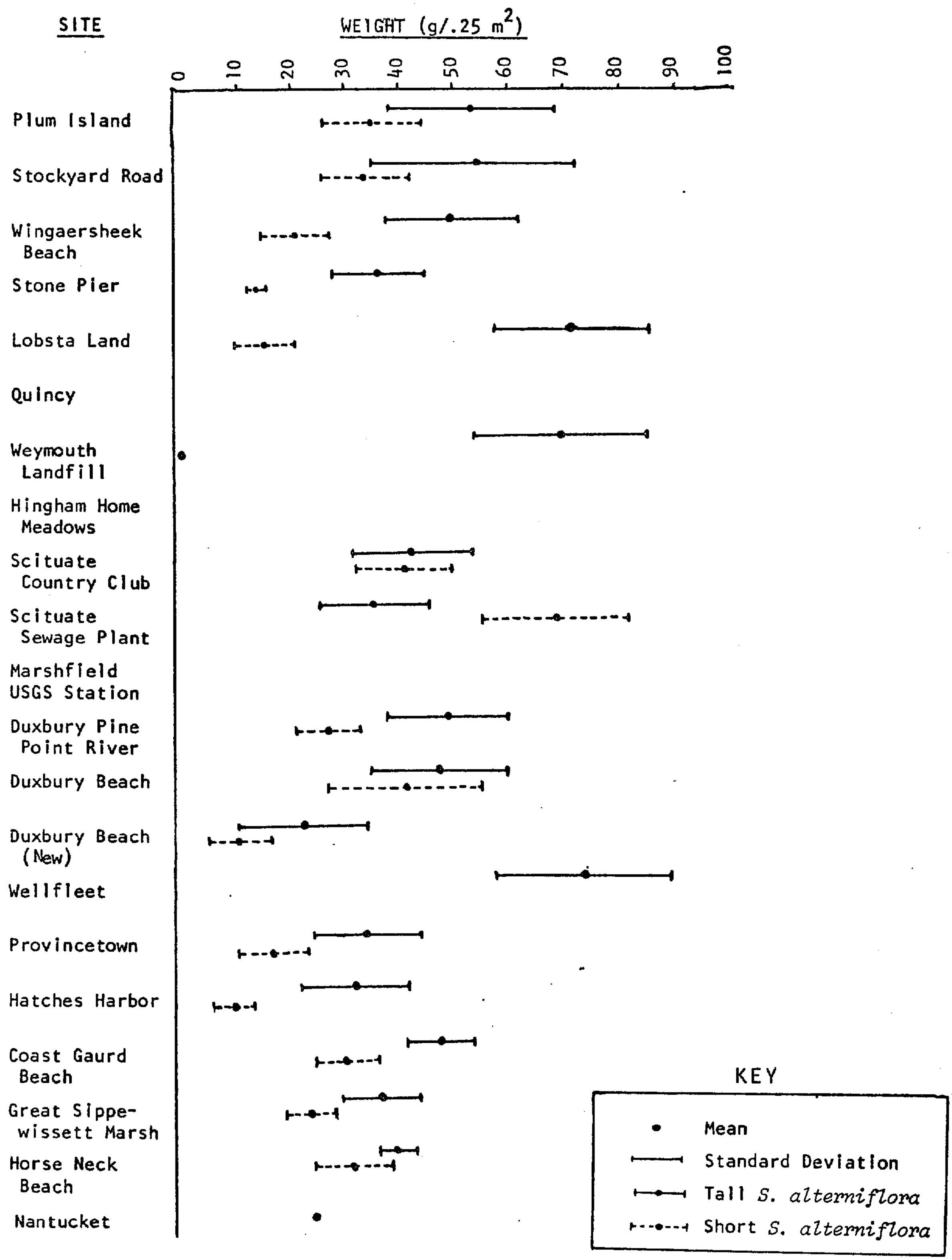

TABLE 2

Selected Massachusetts Salt Marshes
Grouped According to the Standing Crop
Found at Each Site: Tall *Spartina alterniflora*

	Location	Standing Crop $g/.25m^2$	Standing Crop g/m^2	Transect Lengths (m)	No. of Samples
1.	Standing crop greater than 60 $g/.25m^2$ (240 g/m^2)				
a.	Wellfleet	74	296	115, 131, 205	14
b.	Lobsta Land	72	288	197, 107, 270	9
c.	Weymouth	70	280	145	11
2.	Standing crop equal to or greater than 50 $g/.25m^2$ (200 g/m^2)				
a.	Plum Island	55	220	133, 197, 432	8
b.	Stockyard Road	55	220	305, 219, 171	10
c.	Wingaersheek Beach	51	204	151, 27, 84, 227	16
d.	Duxbury Pine Point	50	200	117	10
3.	Standing crop greater than 40 $g/.25m^2$ (160 g/m^2)				
a.	Duxbury Beach	48	192	191, 183	20
b.	Coast Guard Beach (Eastham)	47	188	117, 200, 318	4
c.	Scituate Country Club	44	176	136, 526	20
4.	Standing crop greater than 30 $g/.25m^2$ (120 g/m^2)				
a.	Horseneck Beach	39	156	83	2
b.	Stone Pier, Gloucester	37	148	80, 127	12
c.	Great Sippewisett Marsh	36	144	105, 58	8
d.	Scituate Sewage Plant	36	144	474	3
e.	Provincetown	34	136	364, 493, 136	17
f.	Hatches Harbor	32	128	397, 402, 420	33
5.	Standing crop greater than 20 $g/.25m^2$ (80 g/m^2)				
a.	Duxbury Beach (New)	23	92	22, 32	4

TABLE 3

Selected Massachusetts Salt Marshes
Grouped According to the Standing Crop
Found at Each Site: Short *Spartina alterniflora*

Location	Standing Crop $g/.25m^2$	Standing Crop g/m^2	No. of Samples
1. Standing crop greater than 60 $g/.25m^2$ (240 g/m^2)			
a. Scituate Sewage Plant	69	276	12
2. Standing crop greater than 40 $g/.25m^2$ (160 g/m^2)			
a. Scituate Country Club	42	168	9
b. Duxbury Beach	42	168	2
3. Standing crop equal to or greater than 30 $g/.25m^2$ (120 g/m^2)			
a. Plum Island	37	148	27
b. Stockyard Road	34	136	32
c. Horseneck Beach	31	124	6
d. Coast Guard Beach (Eastham)	30	120	17
4. Standing crop greater than 20 $g/.25m^2$ (80 g/m^2)			
a. Duxbury Pine Point	27	108	6
b. Nantucket*	24	96	31
c. Great Sippewisset	23	92	5
d. Wingaersheek Beach	22	88	10
5. Standing crop equal to greater than 10 $g/.25m^2$ (40 g/m^2)			
a. Lobsta Land	16	64	3
b. Provincetown	16	64	5
c. Stone Pier	14	56	3
d. Duxbury Beach (New)	12	48	5
e. Hatches Harbor	10	40	8
6. Standing crop less than 10 $g/.25m^2$ (40 g/m^2)			
a. Weymouth	2	8	1

* Data from Mr. W. Tiffney

Part of the problem in obtaining a clear comparison between marshes lies in the different numbers of transects that were used, their variation in length, and the unequal sample sizes used for standing crop data. These variations reflect the problems inherent in sampling the marshes so as to obtain representative transects, and the limitations of time. Three transects were set out, except where conditions prevented because the marsh was so limited, or it was so extensive that one line was thought to suffice. Also, it was deemed necessary to make four transects when two of those sampled were very short. The number of samples taken for standing crop evaluations was based on the distance along each transect where *S. alterniflora* was found. Thus, a large number of samples indicates marshes in which the area of *Spartina alterniflora* was relatively extensive, while a smaller number indicates more restricted *S. alterniflora* zones. Also, the transect lengths listed in Table 2 represent totals of transect length, not just the zone covered by *S. alterniflora.* From these data, the percent cover of the *S. alterniflora* zone was calculated and presented in Table 4. The total transect lengths indicate how far one has to go across each of the marshes before a impassable feature is encountered. Such features as a deep marsh channel or the end of the marsh in the intertidal zone are examples. The data shown here give a general picture of the variation to be expected and can be used in a first approximation of comparisons between marshes.

Table 3 lists the standing crop of the short form of *Spartina alterniflora* in the same manner as Table 2. The short form generally has less standing crop than the tall, as would be expected. It also represents the highest zone of the low marsh, not within the optimal environment for this species. As shown in Table 4, the short form is from .3 m to .5 m tall, constrasting with the meter or more height of the tall form. Therefore, each plant has considerably less biomass, and contributes less to the estuary. However, as mentioned above, the density of these plants can make a difference. Occasionally, stands of short *S. alterniflora* are found that are exceptionally dense with a standing crop considerably larger than a less dense stand of the taller form. In such a case, the biomass of the short form will exceed the tall. The Scituate Sewage Plant seems to be an example of this situation. The arrangement of the marshes according to the standing crop in Table 3 shows some differences from the sequence in Table 2, and reflects some of the inherent variations from marsh to marsh, especially in the relative standing crops of various forms of *S. alterniflora* . Only in a few cases is the list arranged in a duplicate fashion. This variability reflects the differences of the salt marshes in proportion to areas of tall form and short form. In overall contribution, both forms need to be considered together, but the area covered by the tall form would be more significant than the short. For most purposes, it is difficult to separate the two types, and it is best to consider the entire *Spartina alterniflora* zone the most significant portions of the salt marsh, from the standpoint of potential estuarine productivity.

Table 5 lists the sampled marshes according to the amount of area

TABLE 4

Standing Crop and Height of *Spartina alterniflora*	WEIGHT g/.25m^2 TALL ave.	S.D.	SHORT ave.	S.D.	NUMBER OF OBSERVATIONS TALL	SHORT	HEIGHT METERS TALL ave.	S.D.	SHORT ave.	S.D.
Plum Island	54.76	29.38	36.60	14.70	8	27	1.0	0.26	0.4	0.09
Stockyard Rd.	54.84	35.37	34.45	15.95	10	32	1.0	0.50	0.3	0.08
Wingaersheek Beach	50.61	25.30	21.53	11.10	16	10	1.0	0.22	0.4	0.06
Stone Pier	37.48	14.81	14.22	1.21	12	3	1.0	0.16	0.3	0.06
Lobsta Land	71.64	26.60	15.81	8.71	9	3	1.0	0.16	0.3	0.00
Quincy										
Weymouth	69.59	30.00	1.68	—	11(10)	1	1.5	0.13	0.3	—
Hingham										
Scituate Country Club	43.78	20.05	41.71	14.32	20	9	0.8	0.18	0.4	0.01
Scituate Sewage Plant	35.78	18.63	68.64	24.57	3	12	0.7	0.08	0.4	0.07
Marshfield USCG Station										
Duxbury Pine Point R.	49.65	20.22	26.72	9.95	10	6	0.9	0.29	0.2	0.07
Duxbury Beach	47.95	24.38	41.94	26.98	20	2	1.0	0.22	0.5	0.00
Duxbury Beach (New)	23.10	21.50	11.51	9.21	4	5	1.0	0.27	0.4	0.06
Wellfleet	73.90	29.15			14(0)	(0)				
Provincetown	33.93	19.16	15.47	13.38	17(0)	11(0)				
Hatches Harbor	32.02	17.38	9.90	6.22	33(14)	8(0)	1.0	0.23		
Coast Guard Beach	46.85	9.60	29.60	11.38	4	17	1.1	0.37	0.4	0.09
Great Sippewisset Marsh	36.05	14.35	22.72	7.47	8	5	0.8	0.20	0.5	0.04
Horse Neck Beach	39.00	5.74	30.69	12.79	2	6	1.0	0.16	0.3	0.12
Nantucket*			24.19			31				

The values in the table are for *S. alterniflora* only, other species which may have occurred with the *S. alterniflora* were not included because the method of sampling was biased against these species. This was done because *S. alterniflora* was the species of concern in this investigation. In the Number of Observations columns the values refer to both the weight and height except where two numbers are given. The value in parenthesis applies to height and the value NOT in parenthesis applies to weight.

* The data for Nantucket were supplied by Dr. Wesley Tiffney of the University of Massachusetts Field Station, Nantucket. The data were collected by Sara Shed on Quaise Point marsh in August 1972.

TABLE 5

Percent Cover of *Spartina alterniflora* Along Transects on Selected Massachusetts Salt Marshes. Marshes grouped according to decreasing values.

Location	Total (rounded off)	Sparse	Pure Tall	Pure Short
1. Percent cover equal to or greater than 70				
a. Duxbury Beach (New)	92	9.9	55.2	27.0
b. Scituate Sewage Plant	78	9.7	16.7	51.3
c. Great Sippewisset Marsh	74	11.7	12.2	50.0
d. Scituate Country Club	73	5.0	48.4	19.4
e. Horseneck Beach	70	2.0	10.0	58.0
2. Percent cover equal to or greater than 50				
a. Hatches Harbor	58	34.6	22.2	0.8
b. Duxbury Point	50	14.5	19.6	16.2
c. Wellfleet	50	3.4	46.9	
3. Percent cover equal to or greater than 40				
a. Coast Guard Beach (Eastham)	41	27.9	3.0	10.4
b. Stone Pier	41		36.4	5.0
4. Percent cover equal to or greater than 30				
a. Plum Island	37	16.1	1.2	20.1
b. Provincetown	33	13.2	16.3	3.9
c. Wingaersheek Beach	32	1.3	23.1	7.4
d. Stockyard Road	30	10.6	1.3	18.2
5. Percent cover equal to or greater than 20				
a. Duxbury Beach	26	8.2	17.4	0
6. Percent cover equal to or greater than 10				
a. Weymouth	10	4.1	6.2	0
7. Percent cover less than 10				
a. Lobsta Land	9	6.8	0.6	1.8
b. Quincy	5	1.8	2.3	0.4
c. Marshfield	4	3.1	0.8	
d. Hingham	0			

covered by the *Spartina alterniflora* zone along the transects. The data are given as percent cover, determined by measuring the distance along each transect in which *S. alterniflora* was found and then computing the amount of cover in relation to the rest of the communities on that transect. Such data are necessary to determine how much of the area should be included in the overall productivity evaluation. In other words, simply measuring the standing crop in a few areas is not really enough; we also need to know how much is present on an areal basis.

The data presented in Table 5 cannot be used as an exclusive value for each marsh, since so many variables are involved, and the only way to get a more accurate value is through detailed mapping. However, we can get some idea of which marshes have more extensive *S. alterniflora* zones from this method. A large total area of the *S. alterniflora* zone can balance off a relatively low standing crop so that a marsh may still be important with regard to estuarine productivity, and a very high rate of productivity might enhance the values in a somewhat smaller zone. For example, as shown in Table 5, the new Duxbury Beach area had the lowest standing crop, but it has the greatest area covered by *S. alterniflora* (92%). This marsh area may still be developing and thus has not yet reached its maximum growth rates. On the other hand, the Weymouth (10%) and Lobsta Land (9%) marshes have some of the lowest values of pure *S. alterniflora* coverage, though they have very high standing crops where the species is best developed. Most of the other marshes fall somewhere in between; interestingly, those with the most extensive marsh areas covered by *Spartina alterniflora* (70% or more) come out in the lower range of standing crop. This information illustrates the importance of considering the many aspects of marsh productivity before any generalized statements are made. Standing crop, while a useful parameter, is not the only value that should be used. The total area covered by the low marsh is very important, but likewise, it alone does not give the entire answer either. Both are important parameters and essential for any ecological evaluations.

Compared to published data and data taken by our own research group at the end of the growing season on the standing crop of salt marshes the data presented here shows low values. Nixon and Oviatt (1973) found that the standing crop of tall *Spartina alterniflora* in a Rhode Island marsh was on the order of 840 g/m^2 while the short form had 432 g/m^2. Our own measurements, made in Wellfleet at the end of the season in 1974, gave values ranging from 656 to 960 g/m^2 for tall *S. alterniflora*. The data in this paper are only roughly half; this leads one to conclude that the time of year when these samples were taken was too early; the samples were taken in August, when the plants might be expected to grow for at least a month These data cannot be compared with other studies made later in the growing season. But, since they were all done about the same time, the different marshes can be compared to each other.

Community Analysis

While a knowledge of the general species make-up of salt marshes may not be as significant as the total exportable productivity, such information does provide a means of evaluating the ecological condition of the marshes. It also can be used in comparisons to determine which marshes are dominated by only a few species and which have many. Generally, marshes with many species of plants are in later stages of succession and thus less productive in terms of estuarine criteria. However, those marshes with high numbers of species represent sites that may have unusual species distributions and therefore may warrent further investigation.

Figure 3 gives the percentage cover of the eight general community types at each site. It compares the overall cover of specific communities to others along the transects. It furnishes representation of the make-up of each marsh, showing which are dominated by high marsh, and which by low marsh. Marshes with a high percentage of *Spartina alterniflora* cover, including sparse, pure short and pure tall, have a correspondingly low value for high marsh cover dominated by *Spartina patens*. This information is useful for interpretation of aerial photographs as well as evaluation of specific marshes.

The frequency with which certain species can be expected to occur in a marsh provides valuable information about the make-up of the marsh. Figure 4 is a bar graph of frequency values for the four most important species that make-up the Massachusetts salt marshes which also are listed in Table 6. Frequency figures represent, by percentage, the number of times one would expect to find a certain species within a specified sample site. Thus, a species with a frequency of 100% would be found in all quadrats sampled, while a species with a 50% frequency would be found in only half of the quadrats. As with cover, marshes with a high frequency of *Spartina alterniflora* have a correspondingly low frequency of *Spartina patens*, and vice-versa. As a member of the high marsh, *Distichlis spicata* (spike grass) is included with the *Spartina patens*. Also included with *S. patens* is *Puccinellia*, whose leaves are nearly indistinguishable from *S. patens*, and were not separated out in this analysis. *Salicornia* (saltwort) is found in nearly all salt marshes, usually associated with the borders of salt pannes (depressions that accumulate sea water and become highly saline). This species has a low frequency and does not contribute much to the overall make-up of the marshes, except for a few marshes on Cape Cod where the frequency exceeds 12%. (The reason for the higher frequency of *Salicornia* in these three marshes is not presently known.)

Table 7 lists the frequency of all species identified on the marsh transects, and includes the data for the species shown in Figure 4. From these data, it is clear that only a few species of plants make up the basic plant community of each marsh. A number of species found occasionally are representatives of other communities which really have no functional bearing on the salt marsh. Included in this category are the last seven

FIGURE 3

Cover of the Eight Community Types at Each Site
(expressed in percent)

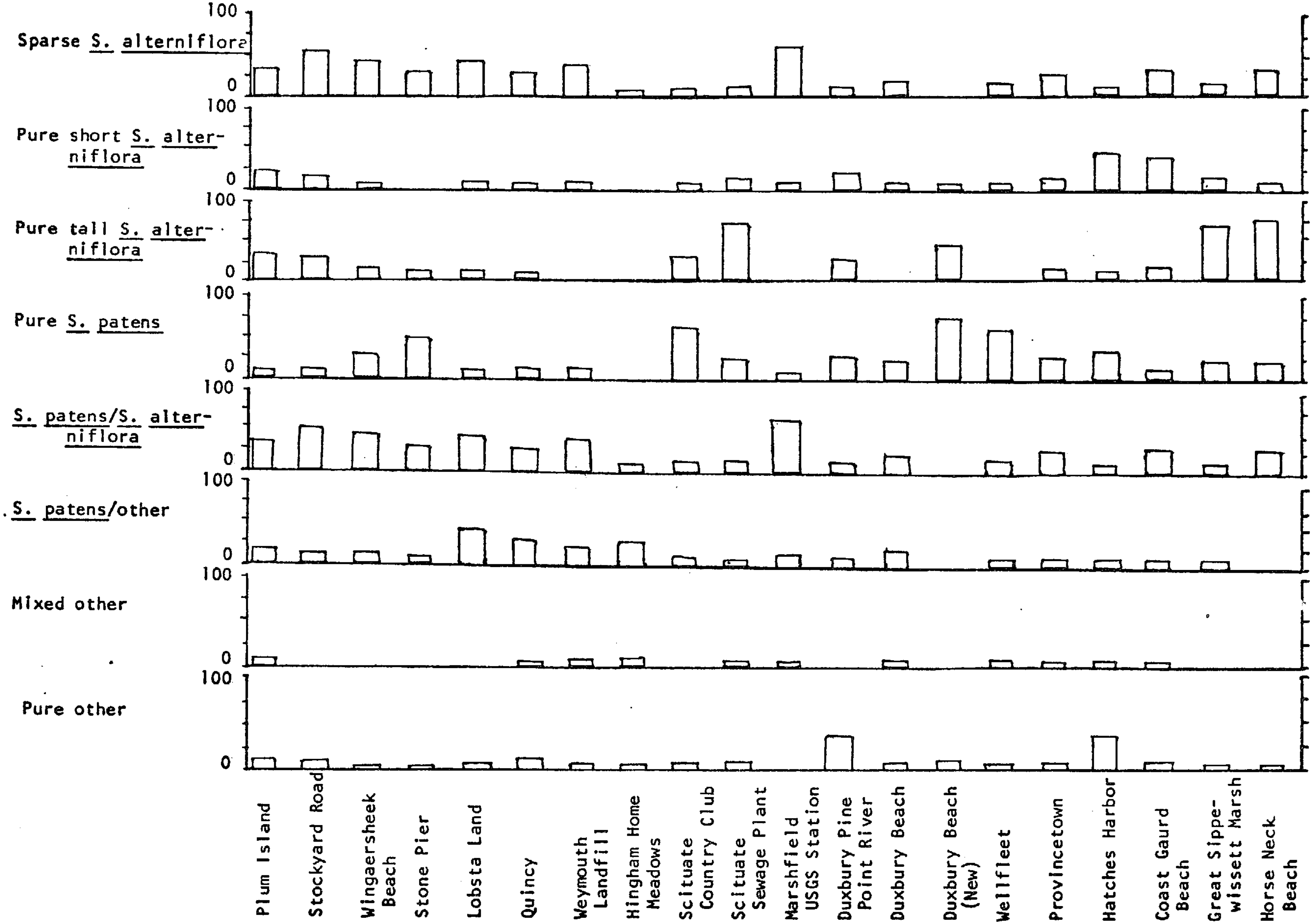

FIGURE 4

Frequency of the Four Dominant Species at Each Site
(expressed in percent)

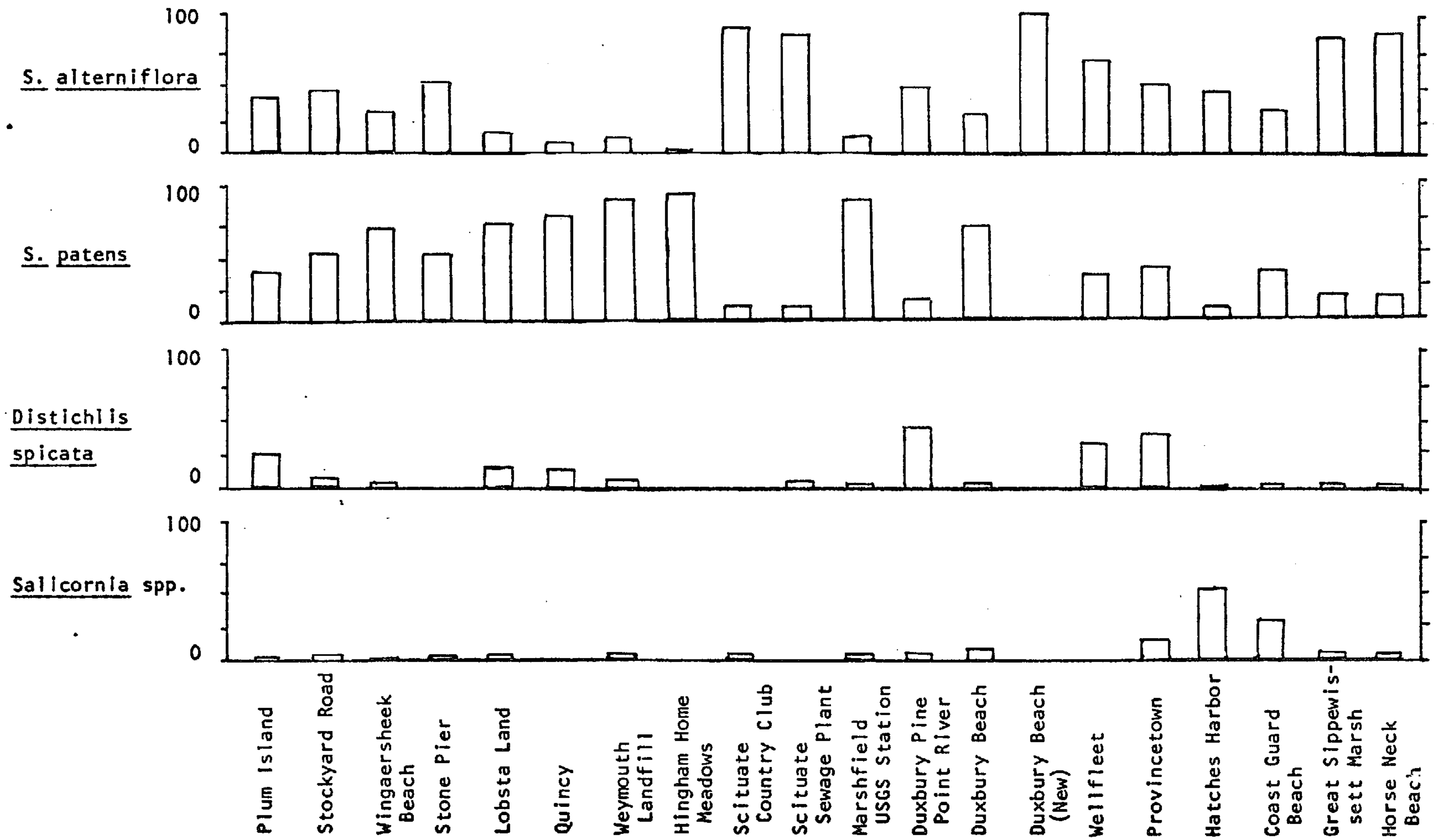

TABLE 6

Percent cover of the eight community types	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippewisset Marsh	Horse Neck Beach
Sparse S. alterni.	16.1	10.6	1.3		6.8	1.8	4.1		5.0	9.7	3.1	14.5	8.2	9.9	3.4	13.2	34.6	27.9	11.7	2.4
Pure short S. alt.	20.1	18.2	7.4	5.0	1.8	0.4			19.4	51.3		16.2		27.0		3.9	0.8	10.4	50.0	57.8
Pure tall S. alt.	1.2	1.3	23.1	36.4	0.6	2.3	6.2		48.4	16.7	0.8	19.6	17.4	55.2	46.9	16.3	22.2	3.0	12.2	9.6
Pure S. patens	12.4	12.5	25.3	34.1	27.0	40.9	44.1	74.6	18.8	2.3	38.8	4.3	45.1		31.9	31.2	5.1	20.9	11.1	8.4
S. patens/alter.	24.9	40.4	33.3	22.1	31.3	21.4	26.9	1.4	3.0	6.1	48.8	5.1	13.0		10.1	19.1	2.0	20.2	9.6	20.5
S. patens/other	11.9	8.5	7.6	1.0	28.8	21.8	13.8	18.3	1.8	2.3	7.0	7.7	12.6		3.7	6.7	5.3	7.3	5.2	
Mixed other	1.5					0.4	1.4	2.8		3.5	1.6		0.2		1.1	1.3	3.7	2.2		
Pure other	11.9	8.4	1.8	1.2	3.5	11.1	3.4	2.8	3.7	5.1		32.5	3.4	7.8	1.7	4.7	29.0	8.0	3.7	1.2
Number of transects at each site	3	3	4	2	3	2	1	1	2	1	1	1	2	2	3	3	3	3	2	1
Number of observations	691	622	470	204	534	175	131	138	606	421	120	114	341	45	385	877	1023	622	146	81

The values in the body of the table represent the percent cover of each of the eight community types in the 20 study sites. The percentages are based on the total number of observations made at the study site (the last line of the table).

TABLE 7

Species Diversity	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham Home Meadows	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippewissett Marsh	Horse Neck Beach
Spartina alterniflora	.400	.445	.315	.502	.137	.077	.113	.004	.897	.836	.102	.459	.256	1.00	.644	.471	.418	.318	.797	.825
Spartina patens	.361	.470	.626	.495	.694	.763	.863	.925	.101	.102	.833	.126	.668		.301	.385	.078	.383	.164	.166
Distichlis spicata	.213	.081	.027	.000	.162	.144	.026		.000	.030	.011	.402	.021		.048	.000	.004	.014	.012	.006
Salicornia spp.	.004	.001	.002	.001	.002		.004		.001		.002	.006	.044		.000	.135	.488	.223	.023	.001
Juncus gerardi	.017		.014			.014		.015		.010	.002							.023		
Atriplex patula	.001	.000		.001	.002	.000	.002		.000	.000	.002		.001		.002					
Plantago spp.	.003	.003	.000	.000	.000					.001	.036	.005	.008						.002	
Solidago sempervirens	.001		.000																.001	
Aster tenuifolius	.000						.002				.008					.001				
Limonium carolinianum		.000	.000		.001					.000		.002	.002		.000	.003	.004	.006		.001
Chenopodium rubrum			.001																	
Suaeda maritima			.001		.001	.002	.001		.000	.018			.000		.004	.004	.008	.000		
Glaux maritima			.012								.003									
Scirpus maritima							.016	.001												
Festuca rubra								.027												
Typha latifloia								.004												
Lythrum salicaria								.003												
Pluchea sp.								.004												
Phalaris arundinacea								.010												
Phragmites communis								.006		.001										
Rhus radicans								.001												
Ammophila breviligulata																		.002		
Total number of observations	6912	6220	4698	2039	5339	1749	1312	1378	6060	4215	1207	1137	3408	450	3847	8872	10230	6220	1465	813
Species diversity	.664	.500	.507	.503	.474	.392	.242	.143	.184	.238	.293	.612	.485	0.0	.493	.611	.581	.701	.337	.291

The values in the body of the table indicate the frequency of each of the species found at the 20 study sites. This value is expressed as a proportion of the total number of observations made at the various sites. The last line of the table is the species diversity for each of the sites. This value was calculated using Simpson's diversity formula $D = 1 - \sum_{i}^{n} p_i^2$ (Simpson, 1949). D = diversity, p_i = the proportion of observations for each of the species at the site. The diversity value ranges from 0.0 to 1.0 with values closer to 1.0 representing greater diversity than values closer to 0.0

species on the list, which are usually found either in fresh water communities or dines; six of these were found only as a group in one marsh - Hingham Meadows - which does not have much in the way of an intertidal marsh system. The typical salt marsh plants at the top of the list occurred irregularly on the transects, and with a low degree of predictability. It is likely that all of these species would be found in each marsh, but at low frequencies, and do not play a major role in the composition of the marsh vegetation. Of all the species listed, only three have high frequencies throughout: *Spartina alterniflora, S. patens* (including *Puccinellia)*, and *Distichilis spicata*. Those marshes where *S. alterniflora* has the greatest frequency for the most part, low marshes, while those with *S. patens* and *Distichlis* are high marshes.

These data are valuable when one is considering the overall composition of a marsh area in addition to its productivity, and the overall cover of any particular species or species group. It is one more parameter useful in evaluating the nature of any particular marsh. Thus, though a marsh such as Duxbury Beach (New) is dominated entirely by *S. alterniflora*, as shown earlier, it has a relatively low standing crop of that species, perhaps indicative that this marsh is so young that the species has not yet taken a firm hold. Hingham Meadows, on the other hand, is dominated by *S. patens* with a low occurrence of *S. alterniflora*, thus suggesting that it is so far along in succession (or has lost its low marsh fringe through erosion) as to be of little value to the estuarine environment. It may, however, have other values related to the larger number of plant species to be found there, also indicative of later stages in marsh succession. Marshes such as Plum Island and Wingaersheek Beach have a relatively rich marsh flora, at least as indicated by the transects, and so can be characterized as being in intermediate stages of succession, and still valuable for estuarine production.

A "species diversity index" such as listed in Table 7, is an indicator of the relative importance of various species in the composition of a plant community. The values are based on the contribution of each species to the structure of the community; those with high diversity values (approaching 1,000) have more species occurring as significant members of the community than those with values approaching 0.000 where one species dominates. Marshes with the highest diversity values are dominated by *S. alterniflora, S. patens, Distichlis, Salicornia,* and *Juncus gerardii;* they are therefore more of a mixture of species than marshes such as Duxbury Beach (New) where only *S. alterniflora* was found on the transects. The index only shows which marshes have more species accounting for the total frequency of species found in eash marsh transect, and does not reflect much about the overall contribution made to the estuary. When considering estuarine productivity, salt marshes with high species diversity are probably not as important as those with low values, if the low value reflects the presence of *S. alterniflora*. However, species diversity values can be used to justify retaining variety in species composition within any given marsh area, so that sites with high diversity might be favored over those with low. It really a l depends on the viewpoint being espoused of the role of any given system.

RELATIVE RANKING OF THE MARSHES

According to information gathered in this study, the intertidal salt marshes of Massachusetts show considerable variation in terms of their importance as sources of organic productivity for estuarine and near marine ecosystems. In the parameters of standing crop and cover of *Spartina alterniflora*, the species responsible for the major portion of marsh productivity reaching the estuarine waters, there is a wide range in marshes from very high productivity to rather low, and from marshes with extensive areas of low marsh (dominated by *S. alterniflora*) to those with mostly high marsh (dominated by *S. patens*). The two parameters, standing crop as an indicator of productivity, and proportion of marsh cover made up of *S. alterniflora*, must be considered together when evaluating the role of a particular marsh in the estuarine food web.

Table 8 is an attempt to assign relative values to these parameters and then to rank the marshes sampled in "ecological priority". For each of the groups in which marshes were placed by the standing crop, a relative ranking number was given to each particular marsh. For the groups in Table 2 (standing crop of tall *S. alterniflora*) the following ranking numbers were assigned: Standing crop greater than 240 g/m^2 = 5; greater than 200 g/m^2 = 4; greater than 160 g/m^2 = 3; greater than 120 g/m^2 = 2; greater than 80 g/m^2 = 1. A similar ranking was done for the standing crop groups in Table 3 (short *S. alterniflora*): standing crop greater than 240 g/m^2 = 5; greater than 160 g/m^2 =4; greater than 120 g/m^2 = 3; greater than 80 g/m^2 = 2; greater than 40 g/m^2 = 1; less than 40 g/m^2 = 0. In Table 5, (percent cover of *S. alterniflora)* the following values were assigned: 70% or more = 5; 50% or more = 4; 40% or more = 3; 30% = 2; 20% =1; 10% or less = 0. These relative values for each marsh were then summed, and the marshes listed first according to the highest sum, and then by either the standing crop, or the percent cover, if that value was exceptionally large. The results of this exercise are shown in Table 8; included in the listing are the actual values for each of the three parameters along with the relative ranking number.

In this evaluation, it is clear that marshes which have the highest standing crop and large cover of *S. alterniflora* will come out on top and therefore can be considered of particular importance in terms of estuarine productivity. In the case of Wellfleet, the highest ranked marsh, there was almost no short form. Therefore, a value of five was given to each standing crop parameter to indicate the highest overall productivity. A marsh with high standing crop values and extensive cover would logically be ranked very high in any relative scale. Other marshes that are listed near the top (Scituate, Duxbury, Pine Point and Horseneck Beach) have varying levels of standing crop, but the total contribution of each form, plus the extensive area covered by *S. alterniflora* results in a high relative ranking. The middle group (relative ranking values of 9 to 7) show somewhat more variations, but in general have lower standing crop and smaller cover values. These marshes are still significant in terms of the estuaries, but not to the same degree as those ranked higher. The lower group (relative ranking values 6 to 5) have standing crop values which are

TABLE 8

Ranking of Marshes Sampled According to Relative Values Combining the Parameters of Productivity (tall and short and cover) of *Spartina alterniflora*. Values in parentheses indicate actual measurements.

Location	Total	Tall Form (in g/m^2)		Short Form (in g/m^2)		Cover (in %)	
Wellfleet	14	5	(296)	5		4	(50)
Scituate Country Club	12	3	(176)	4	(168)	5	(73)
Scituate Sewage Plant	12	2	(144)	5	(276)	5	(78)
Duxbury Point	10	4	(200)	2	(108)	4	(50)
Horseneck Beach	10	2	(156)	3	(124)	5	(70)
Plum Island	9	4	(220)	3	(148)	2	(37)
Stockyard Road	9	4	(220)	3	(136)	2	(30)
Coast Guard Beach (Eastham)	9	3	(188)	3	(120)	3	(41)
Great Sippewissett	9	2	(144)	2	(92)	5	(74)
Wingaersheek Beach	8	4	(204)	2	(88)	2	(32)
Duxbury Beach	8	3	(192)	4	(168)	1	(27)
Duxbury Beach (New)	7	1	(92)	1	(48)	5	(92)
Hatches Harbor	7	2	(128)	1	(40)	4	(58)
Stone Pier	6	2	(148)	1	(56)	3	(41)
Lobsta Land	6	5	(288)	1	(64)	0	(0)
Weymouth	5	5	(280)	0	(0)	0	(10)
Provincetown	5	2	(136)	1	(64)	2	(33)
Quincy		?		?		0	(5)
Marshfield		?		?		0	(4)
Hingham		0		0		0	

respectable, and in some cases much higher than those listed above them, but have very low cover percentages which indicate that only a small portion of the marsh is within the daily tide range and making a contribution to the estuary. The bottom ranked marshes - Quincy, Marshfield and Hingham - have practically no value in terms of estuarine productivity, although they may have certain other features of significance. However, they are out of organic production for the marine ecosystems, at least as determined by this evaluation.

It seems possible to obtain date from this kind of exercise, which might be used by the coastal manager, planner to make difficult value judgements regarding salt marshes. While certainly not a fool-proof method or including all parameters that could be used, looking at standing crop and cover of *S. alterniflora*, and then ranking certain marshes accordingly, gives the manager some idea of how valuable a given marsh might be to estuarine productivity.

As mentioned earlier, not all marshes are the same in terms of this ecological consideration, so the manager and the planner may be faced with difficult decisions regarding the fate of a particular marsh. The kind of ground data gathered in this research coupled with aerial photography and mapping can be used to make relative value judgements regarding that marsh. Using this data as ground truth, and the maps produced from the aerial photographs keyed into this information, one can begin ranking specific marshes in terms of their value to the estuarine environment. It is urged that the rankings based on aerial photography be checked by ground investigations before any final decisions are made. It does seem quite possible to break the salt marshes of Massachusetts down into the following groups: (1) those that are of major importance to the estuarine food web; (2) those that are of intermediate importance; and (3) those that are of little value. While it is to be hoped that <u>all</u> coastal salt marshes will be protected throught state and local laws, if value judgements do become necessary, this information can be useful. Obviously, the marshes in Group I should receive the greatest consideration and be protected from all potential encroachments. Those in Group 2 should also be protected, but evaluations might be necessary on a site by site basis. Group 3 would have the lowest priority, but hopefully remain protected, as other characteristics may be shown significant. The dividing line between gropus is relative and should only be made exact following further study with evaluations of specific marshes, considering more data than is currently available for this approach.

It would seem that those marshes in Table 8 that have relative ranking values of ten or greater should be classed as priority #1. Those marshes with values ranging between five and ten might be grouped as priority #2. Finally, marshes falling below a relative ranking value of five, especially if close to zero, might be considered as priority #3. We feel that with this approach to ground data, and by linking these date to detailed maps, like those prepared for this project, any marsh area in the Commonwealth could be evaluated and ranked. The maps provide a first approximation for this evaluation. Looking at them, it should be clear which marshes have the greatest area of low marsh, an indicator to their contribution to the marine environment. Once this is done, ground studies can determine how a particular marsh compares with those in this study, or other studies. Of course, data for comparative purposes must be gathered in the same manner and at the same time of year as the data in the study being used for comparison. By looking at a broad spectrum of marshes, it is possible to approach the difficult questions of evaluating "ecological significance"; we trust that our work is a step in that direction.

SUMMARY

This report has outlined the relation of salt marsh productivity to the productivity of the whole coastal zone.

The data presented show that there is considerable variation in the standing crops and cover of the tall and short forms of *Spartina alterniflora* in the marshes studied. As would be expected the tall form of *S. alterniflora* usually had a greater standing crop than the short form. However, the short form often covers a more extensive area.

A method is presented for evaluation the relative importance of the sal salt marsh's contribution to the estuarine and marine ecosystems based on the parameters, standing crop and cover.

An analysis is made of the communities found in each of the marshes studied. *S. alterniflora, s. patens, Distichlis spicata* and *Salicornia* species were found to be the most frequent species. The community type with the greatest cover was pure *Spartina patens* (high marsh) followed by *S. patens* mixed with *S. alterniflora* (transition between high and low marshes), pure *S. alterniflora* tall, and pure *S. alterniflora* short (low marsh). The communities associated with the fresh HOH fringe of the high marsh did not have a great cover.

This report presents a method for rapid analysis of individual salt marshes based on two parameters (standing crop and species cover) and for rating the contribution of that marsh to the estuarine and nearshore coastal waters relative to other marshes in Massachusetts.

REFERENCE

Nixon, S. W. and Oviatt. 1973. Ecology of a New England salt marsh. Ecol. Mono. 43:463-498.

Appendix I

Species composition and ground cover of the five communities of mixed species that were recognised in this study.

TABLE 9

Sparse *Spartina alterniflora*	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippowisset Marsh	Horse Neck Beach
S. alterniflora	55.4	64.4	72.8		68.3	40.0	46.7		61.5	58.5	22.5	51.8	53.2	20.0	73.1	49.7	33.9	43.8	53.0	60.0
Salicornia	1.2	0.1	1.4		0.8		5.0				5.0	2.4	0.3		0.6	32.2	46.5	42.1	2.6	
Suaeda maritima			8.6		0.5					0.2			0.3			1.1	0.6			
Distichlis	21.2	4.6			0.3							30.6	2.6					4.4		5.0
Juncus	0.8																			
Atriplex	0.2																			
Solidago	0.3																			
Aster	0.1																			
Scirpus							5.0													
Plantago											65.0									
Glaux											7.5									
Limonium												1.2				0.8	0.4	1.4		
Muck	7.5	9.0	11.4		12.8	28.6	23.3		8.0	19.8		5.3	36.4		24.4	7.9	16.1	7.9	44.3	
Ditch/creek	0.2	3.9	5.7		1.1	31.4	20.0		4.9	17.2		8.8	7.1		1.9	2.3	0.6	0.4		35.0
Panne	12.9	17.3							25.6	4.3						3.0	0.3			
Sand														80.0		2.9	1.4			
Number of observations	1112	659	61		363	31	54		303	408	37	165	280	44	131	1171	3539	1735	171	19

The values in the body of the table represent the percent frequency of the various species found in the sparse *Spartina alterniflora* community. The percentages were calculated by dividing the number of occurrences of each species by the total number of observations made at that site.

TABLE 10

Spartina patens mixed with species other than *S. alterniflora*	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippowisset Marsh	Horse Neck Beach
Spartina patens	53.5	70.2	62.4	90.0	63.8	65.7	77.5	78.5	88.0	63.6	61.1	63.3	62.8		50.4	60.5	57.0	65.0	61.7	
Distichlis	20.9	28.1	13.9		31.4	18.4	16.0		2.0	16,4	14.4	26.7	3.6		28.6	0.2	3.2	0.8	16.7	
Limonium			0.2		0.2								1.3		0.9	1.1	0.2	1.4		
Chenopodium			0.6																	
Glaux			6.8																	
Salicornia		0.2	1.2	5.0	0.2				8.0			3.3	25.3			23.3	22.1	25.8	16.7	
Juncus	8.0		6.7			2.6		0.4			1.1							4.8		
Plantago	0.3	0.4	0.3		+					3.6	16.7	6.7	4.7						3.3	
Atriplex	0.2	0.2		0.5	0.4	0.2	1.0		2.0											
Suaeda					0.1	0.5				7.3					6.4	1.5	6.3			
Aster							1.5				6.7					2.0				
Phalaris								5.4												
Phragmites								3.1												
Pluchea								1.9												
Lythrum								0.8												
Typha								2.3												
Festuca								0.8												
Muck	2.5	0.4	4.4		3.4	7.2				9.1			2.3		5.9	10.3	11.0	0.4		
Ditch/creek	0.3	0.4	3.0		0.5	4.6		6.9												
Panne			0.3																	
Sand															4.5	1.5	0.3			
Number of observations	822	529	357	20	1538	381	181	252	109	97	84	88	430		142	594	542	454	166	

The values in the body of the table represent the percent frequency of the various species found in the *S. patens* mixed with species other than *S. alterniflora* community type. The percentages were calculated by dividing the number of occurrences of each species by the total number of observations made at that site.

TABLE 11

Spartina patens mixed with Spartina alterniflora	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippowisset Marsh	Horse Neck Beach
S. alterniflora	32.9	34.1	29.0	24.5	22.5	16.4	7.7	25.0	32.7	11.7	16.5	23.3	9.6		10.9	29.7	12.1	21.3	21.7	58.2
S. patens	56.5	57.8	63.2	74.3	60.5	54.6	86.4	55.0	54.5	86.9	71.6	60.0	63.1		66.2	22.5	68.3	61.9	61.7	38.2
Distichlis	5.7	1.4	1.2	0.2	3.4	1.4						1.7						0.7	6.7	2.4
Glaux			1.0								0.2									
Atriplex		0.1		0.2	0.3						0.5		0.6							
Limonium		0.1			0.1													0.4		0.6
Suaeda					0.3	0.4			1.8							0.2	1.2	0.1		
Salicornia	0.6	0.2		0.2	0.1		0.2						1.9			1.3	5.4	11.6	6.7	0.6
Plantago	0.6	0.5		0.2							0.5		1.0						0.8	
Juncus	0.4										0.2									
Solidago	+																			
Aster											0.6									
Muck	3.1	4.6	3.7	0.2	11.4	18.9	5.6		10.9	1.4	10.0	15.0	21.4		22.9	14.9	11.2	3.7	0.8	
Ditch/creek		0.3	1.9		2.7	8.2		20.0					2.3					0.3		
Panne		0.8	0.7																	
Sand																1.4	1.7			
Rock		0.5																		
Number of observations	1720	2513	1565	451	1671	374	352	19	182	257	585	58	443		389	1694	204	1256	140	166

The values in the body of the table represent the percent frequency of the various species found in the S. patens mixed with S. alterniflora community type. The percentages were calculated by dividing the number of occurrences of each species by the total number of observations made in this community type at each site.

TABLE 12

Mixed other

	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippowisset Marsh	Horse Neck Beach
Distichlis	55.0						10.0			41.2			80.0		72.8		3.3	1.7		
Scirpus							50.0													
Suaeda							5.0			22.9					2.8	3.8	1.6			
Salicornia	0.5						5.0									48.8	67.1	41.7		
Juncus	22.5									20.0								8.3		
Solidago	1.5																			
Plantago	3.0									0.6										
Atriplex										0.6					4.3					
Lythrum								5.0												
Scirpus								2.5												
Festuca								87.5												
Rhus								5.0												
Phragmites										1.8										
Limonium										0.6						3.8	5.1	2.5		
Ammophila																		1.7		
Muck	12.0					40.0	30.0			12.4			20.0		11.4	22.5	9.8	11.7		
Ditch/creek	5.5					60.0												4.2		
Sand															8.6	21.2	13.1			
Number of observations	103					7	18	38		147	20		7		42	115	378	137		

The values in the body of the table represent the percent frequency of the various species found in the mixed other community type. The percentages were calculated by dividing the number of occurrences of each species by the total number of observations made in this community type at each site.

TABLE 13

Pure other	Plum Island	Stockyard Road	Wingaersheek Beach	Stone Pier	Lobsta Land	Quincy	Weymouth Landfill	Hingham	Scituate Country Club	Scituate Sewage Plant	Marshfield USCG Station	Duxbury Pine Point River	Duxbury Beach	Duxbury Beach (New)	Wellfleet	Provincetown	Hatches Harbor	Coast Guard Beach	Great Sippowisset Marsh	Horse Neck Beach
Juncus	1.0		16.6			6.2		50.0		2.6								18.6		
Distichlis	68.4	52.7	16.6	33.3	92.3	87.5				10.5		100%	30.8		70.0		0.3			
Suaeda										7.9										
Salicornia													15.4			57.8	72.3	52.5	14.3	
Muck	3.2	3.6								5.3			7.7		10.0	7.8	2.0			
Ditch/creek		1.8	41.7		7.7	6.2	100%	50.0	15.4	50.0			46.2		20.0	14.0	6.2			100%
Panne	27.4	43.6	25.0	66.6					84.6	23.7						18.8	0.8		85.7	
Number of observations	822	522	84	24	186	194	44	38	244	215		370	116	35	65	417	2967	497	54	10

The values in the body of the table represent the percent frequency of the various species found in the pure other community type. The percentages were calcualted by dividing the number of occurrences of each species by the total number of observations made in this community type at each site.

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